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(56) Documents Cited
JP 040238714 A
US 5180024 A
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US 4867474 A
US 4611815 A

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(54) Abstract Title
Pneumatic vehicle suspension for the adjustment of ride height

(57) A vehicle suspension system comprises gas spring 22, 24, 26, 28 associated with each of the vehicle's wheels, a reservoir 38, a compressor 12 and a pressure sensor 42, where all of which are connected to main line 18 of a pneumatic circuit by respective valves 30, 32, 34, 36, 40. The valves are connected to pressure sensor, and are controlled by control unit 44 to measure the pressure for various functions such as monitoring the vehicle's weight and fault diagnosis. Control unit 44 is arranged to respond to a request for an increase in the ride height by checking the operation of the exhaust valve and only increasing the ride height if the exhaust valve is operable to release gas from the springs.

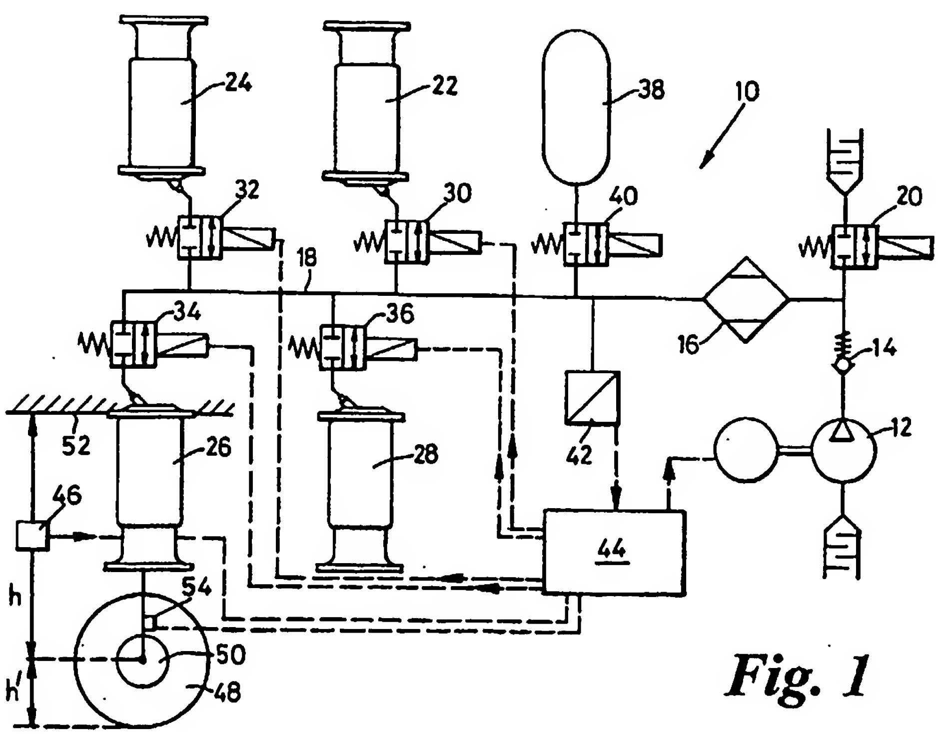

Fig. 1

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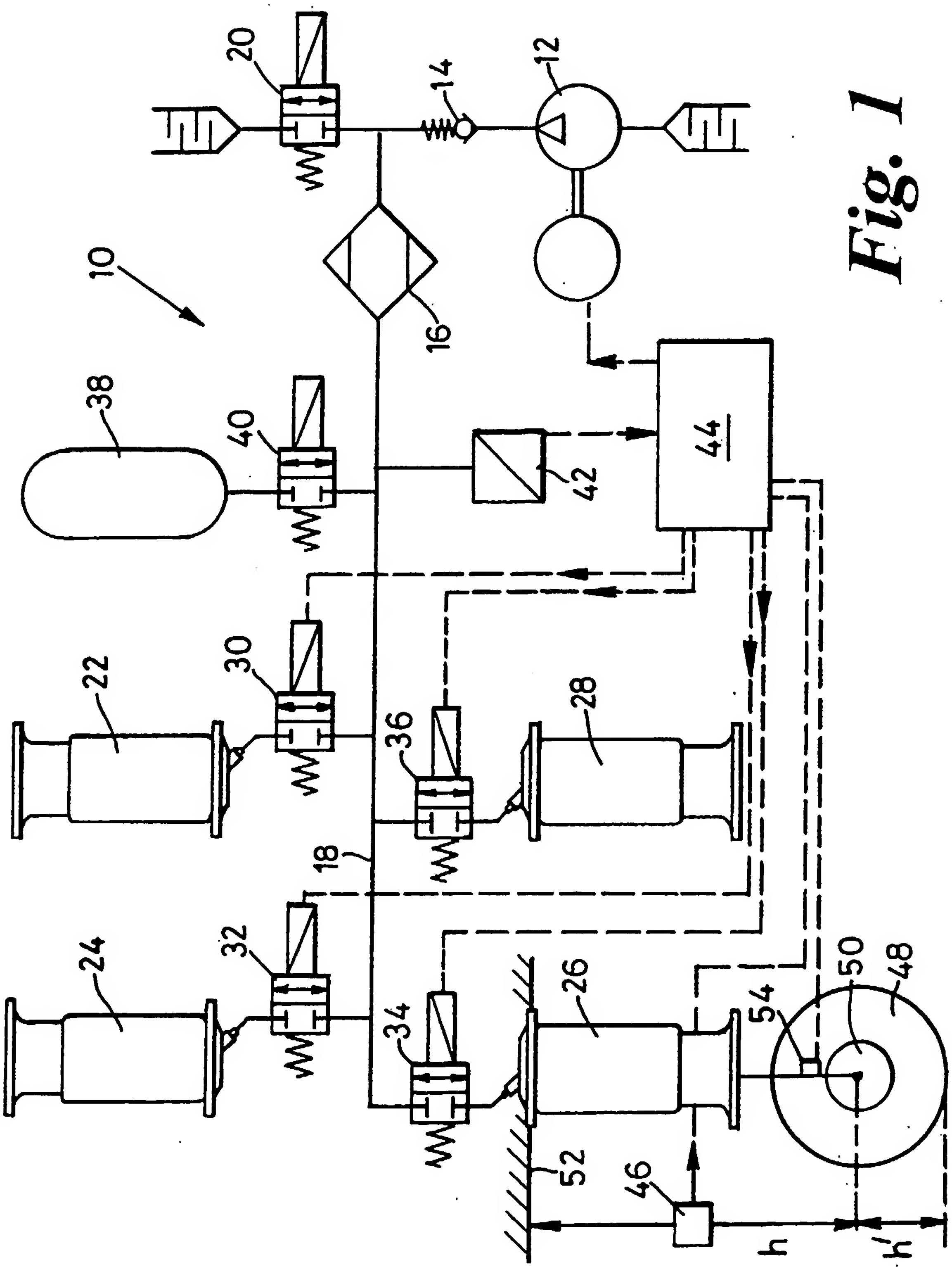

Fig. 1

Vehicle Suspensions

The present invention relates to air suspension systems for vehicles.

It is known, for example from DE 19603593, to measure the pressure at various points in a vehicle air suspension system using a single sensor. It is an aim of the present invention to provide an improved vehicle air suspension using information from such a sensors and from other types of sensors.

The present invention provides a suspension system for connecting a plurality of vehicle wheels to a vehicle body, the system comprising a pneumatic circuit including a source of pressurized gas, gas springs for supporting the vehicle body, an inlet valve which can connect the gas springs to the source of pressurized gas to increase the ride height of the vehicle, an exhaust valve which can release gas from the gas springs to decrease the ride height of the vehicle and control means arranged to control the valves and to respond to a request for an increase in ride height by checking the operation of the exhaust valve and only increasing the ride height if the exhaust valve is operable to release gas from the springs.

Preferably the control means is arranged to check the operation of the exhaust valve by sending a signal to open the exhaust valve and subsequently monitoring the pressure in part of the system connected to the exhaust valve to check that it decreases at at least a predetermined rate.

Preferred embodiments of the present invention will now be described by way of example only with reference to the accompanying Figure 1 which is a diagrammatic representation of a suspension system according to the invention.

A vehicle air suspension system comprises a pneumatic circuit 10 comprising an electric compressor 12 supplying air under pressure via a non-return valve 14

and an air dryer 16 to a main pneumatic line 18. An exhaust valve 20 is provided which can be opened to exhaust the line 18 to atmosphere. Four gas springs 22, 24, 26, 28 are each connected to the line 18 by respective spring valves 30, 32, 34, 36 which can each be opened to connect the respective spring to the line 18 or closed to isolate the respective spring. An air pressure reservoir 38 is also connected to the line 18 by a reservoir valve 40 which can also be opened to connect the reservoir to the line 18 or closed to isolate the reservoir. Finally a pressure sensor 42 is connected to line 18 to measure the pressure in it. A suspension control unit 44 controls all of the valves 20, 30, 32, 34, 36, 40 and the compressor 12 to control the ride height of each of the wheels in response to signals from the pressure sensor. The control unit 44 also receives signals from ride height sensors 46 each associated with one of the wheels 48 which produce signals indicative of the distance between an unsprung part of the suspension which moves vertically with the wheel hub 50, such as the steering knuckle in the front wheels, or part of a beam axle close to the respective wheel, and a sprung part of the vehicle, such as part of the body 52. It may also receive signals from one or more accelerometers indicating acceleration of the vehicle body in the longitudinal, lateral and vertical directions.

At regular intervals when it will not interfere with the normal control of the suspension system, the control unit 44 is arranged to close the exhaust valve 20 and all but one of the other valves 30, 32, 34, 36, 40 so as to connect the pressure sensor to one of the gas springs 22, 24, 26, 28 or the reservoir 38, and to record the pressure measured by the sensor 42. This enables the control unit to measure the pressures in each of the gas springs and the reservoir 38. This measurement of the various gas pressures can then be used in various ways as will be described below.

In order to determine the total sprung weight of the vehicle, including its load, the control unit measures the pressures of each of the gas springs 22, 24, 26,

28. These pressures each give a measurement of the load on the gas springs, and the loads can be added together to give a measurement of the total weight of the vehicle, or simply of the load carried by the vehicle. The conversion of pressures to loads will generally depend on a number of factors, including in particular the effective cross sectional area of the gas spring piston. This cross sectional area is often arranged so as to vary with the ride height of the vehicle, and is therefore variable but known. The loads can therefore conveniently be determined using look-up tables. This weight can either be displayed continuously to the driver by means of, for example, an LED display in the driver's compartment. Alternatively, or in addition, it can be used to trigger an alarm, such as a flashing light or buzzer, if the total vehicle weight exceeds a predetermined maximum, indicating overloading. Where the vehicle includes an on-board system for controlling the level of inflation of its tyres, the vehicle weight can be input to a tyre inflation control system which then controls tyre inflation in response to the measured weight of the vehicle. Finally the vehicle weight can be used to modify a roll control function in the vehicle suspension. For example where the roll control system measures lateral acceleration of the vehicle and produces a roll correction force which is calculated, for example, so as to keep the vehicle level, the vehicle weight will affect the relationship between the lateral acceleration and the force required to keep the vehicle level. If the weight is measured as described above this can be input to the roll control system which can respond accordingly. This will apply whether the roll correction force is provided by controlling the inflation of the gas springs in the system shown in Figure 1, or by an active anti-roll bar.

The individual wheel loads can also be used to refine the operation of the active suspension system. This is because the ride height sensors 46 measure the distance h from the wheel hubs 50, to part of the vehicle body 52, whereas the measurement actually required by the system to operate optimally is that of the

distance (h+h') between the body 52 and the ground, which will also be affected by the level of tyre squash. The distance h' between the hub 50 and the ground is dependent on the tyre pressures and the load on the wheel. The control unit 44 therefore uses the measured wheel loads, and tyre pressure measurement from a tyre pressure sensor 54, to modify the measured ride heights to take tyre squash into account. This enables, for example, the vehicle levelling function of the system to operate more accurately. Since the height h' will also depend on the type of tyre on the wheel 48, which could obviously be changed by the driver, the control unit 44 is also programmable to account for changes in tyre type. Alternatively the tyre pressure sensor, which can be of the type embedded in the tyre, can also be arranged to transmit to the control unit 44 further information to enable more accurate determination of the distance h' between hub and ground, for example the tyre type and temperature. Such sensors are disclosed, for example in WO96/28311.

A further feature of the control of the system is that, because the pressure in the reservoir 38 and the gas springs 22, 24, 26, 28 is continuously monitored, the inflation of the gas springs can be controlled to avoid accidental deflation. When the control unit 44 determines that one of the gas springs needs to be inflated, it checks the pressure of that spring and the reservoir. If the reservoir pressure is higher it opens the reservoir valve 40 and the valve of the relevant gas spring to connect the gas spring to the reservoir to inflate the gas spring. If, on the other hand the reservoir pressure is lower than the spring pressure, the reservoir valve 40 is closed to cut off the reservoir from both the gas spring and the compressor 12, and the gas spring valve is opened to connect the gas spring to the compressor so that it can be inflated directly from the compressor. This ensures that all the air from the compressor is fed directly to the gas spring to inflate it quickly thereby minimizing vehicle lifting times. It also means that there is no need for a non-

return valve to prevent accidental deflation of the gas spring. Furthermore it ensures that the pressure reservoir 38 can be used whenever its pressure is higher than that of the gas spring which is to be inflated.

The control unit 44 is also arranged to monitor the system continuously for faults, particularly in the valves. It does this by sending a signal to one of the valves to open or close it and then monitoring the gas pressure in part or the system to determine whether the expected pressure changes result. For example, to check the operation of one of the spring valves 22, 24, 26, 28 the control unit sends a signal to open it, thereby connecting the pressure sensor to the gas spring, and then checks that the oscillations in gas pressure expected from the motion of the wheel associated with that spring over a surface are detected. If they are not a warning can be given to the driver or a fault stored in memory for interrogation using service diagnostics equipment. Similarly to check the operation of the exhaust valve, the main line 18 and drier 16 can be connected briefly to the reservoir 38 to increase their pressure, then a signal then sent to open the exhaust valve and the subsequent decay of pressure monitored. If the pressure does not decay as quickly as expected this indicates that the exhaust valve is stuck closed. A stuck closed reservoir valve would be indicated by too rapid an increase in pressure when running the compressor to charge the reservoir while the reservoir valve is signalled to be open. A stuck open reservoir valve would be indicated by a failure of the pressure in the main line 18 to drop rapidly when the exhaust valve 20 is open and the reservoir valve 40 signalled to be closed. Finally a slow increase of pressure when charging the reservoir may be indicative of a faulty compressor or a leak in the air supply.

Checking the operation of the exhaust valve is particularly important where the control unit 44 is arranged to allow the ride height of the vehicle to be varied. In off road vehicles it is known to have a choice of ride heights so that for off-road

driving the ride height can be increased to give greater wheel travel, and for on-road driving the ride height can be decreased again to reduce wind resistance and improve handling particularly through corners. The control unit 44 is then arranged to respond to a request for an increase in ride height by first checking the operation of the exhaust valve 20 as described above to ensure that it can release air from the system. Only of the exhaust valve is operating properly is the ride height increased. If it is not, the request for an increased ride height is overridden. This helps to ensure that the vehicle ride height is not increased to a level above that which is optimum for on-road driving if it will not be possible to reduce it again afterwards. It will be appreciated that this check could in fact be made under the same conditions using a different means for checking the proper operation of the exhaust valve. However, methods which check for the exhaust of air from the system, rather than simply the opening of the valve, are preferable because the latter would not detect other problems such as a blocked pipe.

CLAIMS

1. A suspension system for connecting a plurality of vehicle wheels to a vehicle body, the system comprising a pneumatic circuit including a source of pressurized gas, gas springs for supporting the vehicle body, an inlet valve which can connect the gas springs to the source of pressurized gas to increase the ride height of the vehicle, an exhaust valve which can release gas from the gas springs to decrease the ride height of the vehicle and control means arranged to control the valves, wherein the control means is arranged to respond to a request for an increase in ride height by checking the operation of the exhaust valve and only increasing the ride height if the exhaust valve is operable to release gas from the springs.

2. A system according to claim 1 wherein the control means is arranged to check the operation of the exhaust valve by sending a signal to open the exhaust valve and subsequently monitoring the pressure in part of the system connected to the exhaust valve to check that it decreases at at least a predetermined rate.

3. A vehicle suspension system substantially as hereinbefore described with reference to the accompanying drawings.

Application No:	GB 0213172.0	**Examiner:**	Richard C. C. So
Claims searched:	1 and 2	**Date of search:**	9 July 2002

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): B7D (DCA, DCX).

Int Cl (Ed.7): B60G (17/015, 17/04, 17/048, 17/052, 17/056).

Other: Online: EPODOC, JAPIO, WPI.

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	US 5342080 A	(MACHIDA). See figures 1 and 2 and column 4 lines 18 to 32.	-
X	US 5180024 A	(ETO). See figures 1 to 2 in particular to discharge valve 21 and column 6 lines 23 to 38.	1.
A	US 4867474 A	(SMITH). See figures 4 and 5 and column 6 lines 10 to 18.	-
A	US 4669749 A	(TANAKA et al.). See figure 1 and column 3 lines 23 to 33 and 47 to 49.	-
X	US 4611815 A	(SASAGE et al.). See whole document especially figures 1 and 2 in particular to controller 30, column 1 lines 29 to 61 and column 2 line 63 to column 3 line 11.	1 and 2.
X	JP 4238714 A	(HINO MOTORS LTD.). See abstract and figures.	1.

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		